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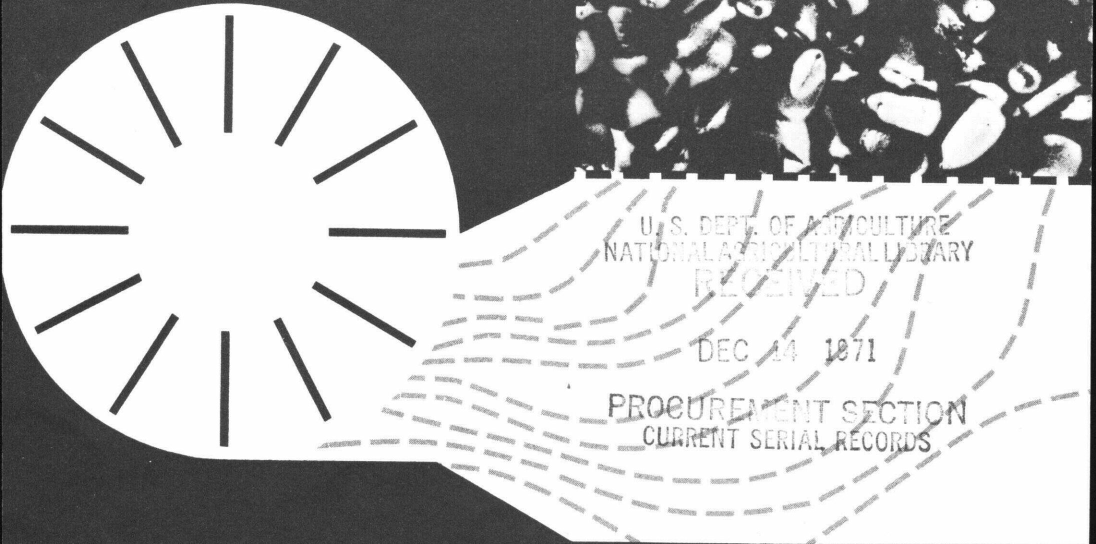
DRYING SHELLED CORN AND SMALL GRAINS



FARMERS' BULLETIN NO. 2214

UNITED STATES DEPARTMENT OF AGRICULTURE

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DRYING SHELLED CORN AND SMALL GRAINS

Prepared by the Agricultural Engineering Research Division, Agricultural Research Service.

Hazards of storing shelled corn and small grains on the farm can be reduced if excess moisture is removed from the grain. A system for drying grain on the farm is part of a larger system for producing, harvesting, handling, and storing grain in such a way that its quality is suitable for its intended use as feed or food or for processing. The suitability of a drying system depends as much on how well the system fits in with harvesting and handling operations as it does on the efficiency of the drying operation itself. A drying operation that is satisfactory and economical for corn to be fed on the farm may not be suitable if the corn is to be sold in the market.

There is no simple rule for the choice of one particular drying method over the others, but a number of things influence the economy or overall satisfaction given by each. These include the following:

- Annual quantity of the crop to be dried.
- Ultimate use to be made of the grain.
- Availability of buildings suitable for drying.
- Availability of power and fuel.
- Harvesting methods and timing of harvest.
- Availability and competence of service from the manufacturer or distributor.

The economy and smoothness of operation of any drying method depend on experience and judgment of the operator.

Methods of Drying

There are several common methods of mechanically drying shelled corn and small grains on the farm. Each has its advantages. All depend on moving air through the grain. None of these is the "best," but one may be better adapted to a given situation than another. In this leaflet the methods will be classed as follows:

1. Batch drying in a self-contained drier,
2. Batch drying in a storage bin,
3. Drying in storage with unheated air,
4. Drying in storage with supplemental heat,
5. Layer drying in storage.

In any of these methods the grain dries first where the air enters the grain and last where the air leaves. A drying front passes through the grain in the direction of airflow. In high-temperature drying some grain becomes too dry and some remains too moist when the desired average moisture level is reached. This may be taken care of by mixing the grain. In low-temperature drying the driest grain will dry to, or only slightly below, the desired final moisture. It is necessary to move the drying front through the entire mass of grain, and when this is done there will not be much moisture difference between top and bottom grain.

Batch Drying in a Self-Contained Drier

Self-contained batch driers are usually semiportable. They consist essentially of a grain-holding compartment through which air is passed from a tractor-powered or motor-powered fan. The air is heated, usually with liquefied pe-

troleum (LP) gas, to a predetermined temperature. When one batch has finished drying, the compartment is emptied and refilled with wet grain.

It is desirable for such a unit to have a daily drying capacity about equal to the daily harvest. With such a balance and with a suitable arrangement for prompt loading and unloading, this system permits an uninterrupted harvesting-drying operation. The first cost of this equipment is high. Its use is most economical when a large number of bushels are dried each season by each unit.

The capacity in bushels per hour that can be dried is influenced largely by the grain moisture content. The capacity can be increased by raising the air temperature (burning more fuel). The air temperature is controlled by a thermostat. It is so easy to turn the thermostat that an operator is tempted to raise the temperature whenever the drying operation seems too slow. A high temperature does speed up the drying but may damage the grain.

Grain dried with air temperatures above 110° F. will germinate poorly, if at all. As the temperature is increased, internal cracking of the kernels and surface checking become more severe. Grain dried with air temperatures above 130° to 140° F. is inferior for many uses. Such grain is not suitable for the general market, even though the buyer may not be able to detect the damage immediately. On the other hand, grain that is to be fed to livestock appears to lose little of its nutritive value from drying at temperatures up to 180° to 200° F. The purpose for which the grain is intended, therefore, has a big effect on the capacity of a given drying unit and may be a determining factor in the choice of a drying method.

The variation in moisture content when the average moisture has reached the desired level may cause problems in storage. If the wetter and drier grain is completely mixed before it is moved into storage, the moisture content will tend to equalize. In some driers the grain is circulated continually to avoid extreme differences.

The temperature of the grain does not reach the heated air temperature, but when drying is completed the grain is too warm to be put into unventilated storage. After drying is completed the burner may be shut off and the fan used to cool the grain before it is removed from the drier. This cooling operation may take from 20 to 40 percent of the total time the grain is in the drier. If the cooling period could be avoided the daily capacity of the drier would be increased substantially. This can be done by moving the warm grain directly to a ventilated storage without cooling it in the drier.

A storage equipped for aeration of the grain after drying is a logical part of a drying system using a batch drier. Any bin adapted for drying is adequate for such cooling. An aeration system for cooling alone can be relatively simple. An 80-watt motor-driven fan is adequate for this purpose in a 2,600-bushel bin. One simple arrangement in a steel bin is shown in figure 1.

Continuous-flow driers are very much like the above batch driers, but the grain moves through the grain compartment of the drier, usually flowing downward as grain is continuously removed from the bottom. This avoids the necessity for loading and unloading periodically. This type of drier is best suited to 24-hour operation. The grain is cooled by continuously blowing unheated air through a cooling section in the lower part of the grain compartment. The grain is cooled on its way to the discharge. This provision for cooling can be

eliminated if aerated storage is available, and thus the capacity of a given size of drier can be increased.

Batch Drying in a Storage Bin

A steel bin with a false floor can be used as a batch drier. Grain is spread evenly over the floor to a depth of 2 to 3 feet. Heated air is forced up through the grain. When the batch is dry, it is removed and wet grain is put into the bin. With this method of drying, it is necessary to provide for:

- A uniform depth of grain
- Prompt removal of grain and refilling of bin
- Mixing the grain after drying
- Cooling the grain either in the drier or in storage

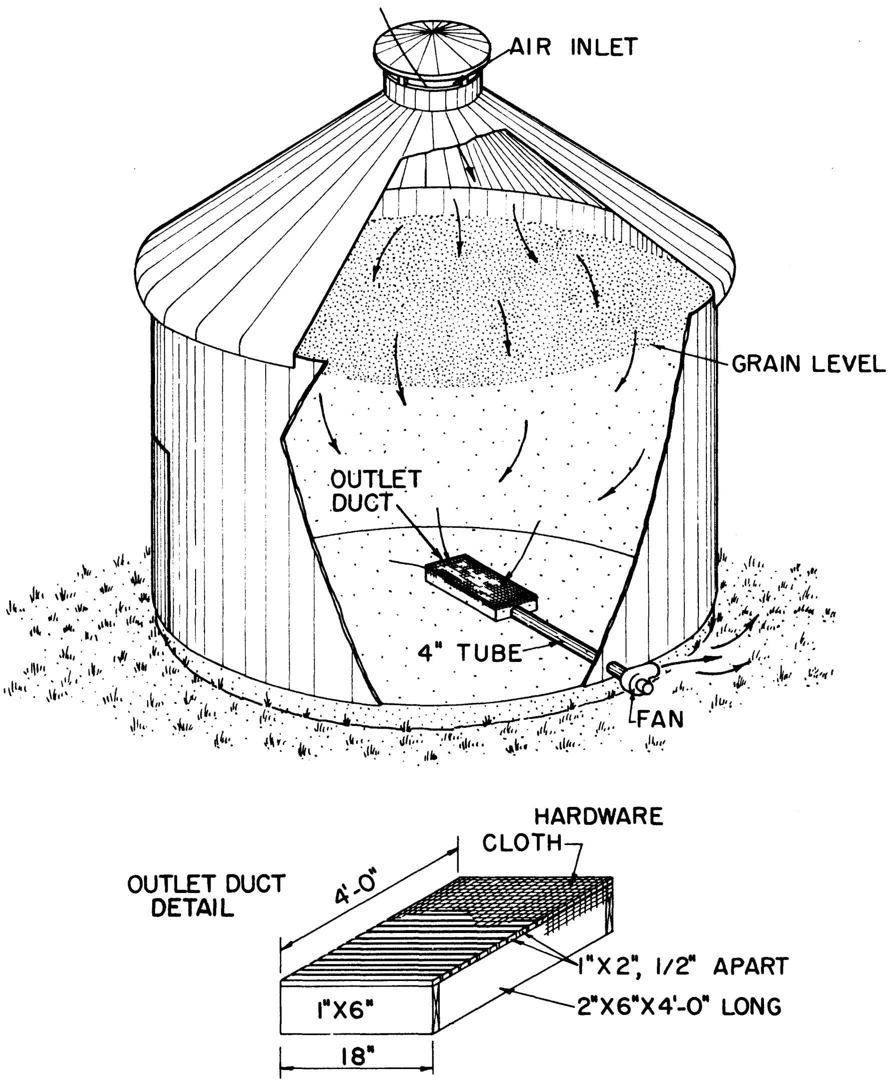

Figure 1.—Simple arrangement for cooling dried grain in storage. Do not use this arrangement for drying.

Limiting the air temperature in keeping with the use to be made of the grain

The operator can adjust the size of batch by loading to any desired level. With experience he can adjust the depth of the grain bed in accordance with the initial moisture content. After the drying season the bin can be filled to capacity and used for storage.

Drying in Storage With Unheated Air

In most climates in the United States, grain can be dried to a satisfactory moisture content by ventilation with unheated air. This method eliminates all hazard of fire caused by drying.

Grain is put in a bin with a perforated false floor, and air is blown through the grain from beneath the floor. It may take several weeks to finish the drying, but the ventilation prevents temperature rise from respiration of the undried grain. As explained before, the bottom layer will dry first, and little if any drying will occur in the top layer until all the rest of the grain is almost dry.

Since the top layer retains its initial moisture for virtually all the drying period, an adequate volume of airflow is essential to push the drying front through all the grain in a limited time. Otherwise, some of the grain will mold before it is dried. The airflow it takes to do this depends on the moisture content, the weather conditions, and even on the amount of mechanical damage to the grain. Under average conditions in the Corn Belt an airflow of 5 cubic feet per minute (c.f.m.) for each bushel to be dried will be adequate for shelled corn with 25-percent moisture content when put in the bin. If the initial moisture is down to 20 percent, it will take about 2 c.f.m. per bushel.

Table 1 shows the airflow requirements for oats, shelled corn, and wheat. For other grains the airflow requirements vary, depending on the per bushel weight. The relation of fan horsepower to grain depth depends on the resistance to airflow. Soybeans have about the same requirements as corn but should be dried to a lower moisture level. Barley and rough rice with 20-percent moisture take about the same amount of air as oats with 25 percent. Grain sorghum has about the same requirements as wheat.

Drying in Storage With Supplemental Heat

The recommended air volumes for unheated air drying are usually adequate for drying grains before serious molding or other damage occurs. There are years, however, when the humidity stays unseasonably high or when grain cannot be harvested in good condition. Provision for "supplemental heat" assures that the drying may be continued even in the worst weather. Supplemental heat is artificial heat used as needed for drying in storage. The air temperature is increased by 10 to 20 degrees for part or all of the drying period. Drying with supplemental heat is not to be confused with batch drying. With supplemental heat, the atmosphere supplies a substantial portion of the heat for evaporation, whereas with batch drying virtually all the heat for evaporating water is supplied by fuel.

The building and the fan and duct systems are similar for unheated air drying and for supplemental heat drying. The heat is usually supplied by a relatively small LP gas or natural gas burner. The capacity of the burner is selected to raise the temperature of the air 10 to 20 degrees when the fan is delivering its normal volume. The supplemental heater may be controlled either manually or automatically.

Automatic controls include humidistats, thermostats, and time clocks. They may be either "mod-

TABLE 1.—*Fan requirements for drying oats, shelled corn, and wheat with unheated air from different percentages of moisture content and at various practical depths*

Grain moisture content (percent)	Recommended minimum airflow rate per bushel	Practical grain depths	Static pressure [1]	Maximum quantity that can be dried per fan horsepower [2]
	Cubic feet per minute	*Feet*	*Inches, water gage*	*Bushels*
WHEAT				
20	3	4	1.2	830
		6	2.3	440
18	2	4	.8	1,880
		8	2.5	600
16	1	8	1.3	2,300
		10	2.0	1,500
OATS				
25	3	4	0.8	1,250
		6	1.7	590
20	2	6	1.1	1,360
		8	1.8	830
18	1½	8	1.4	1,430
		10	2.0	1,000
16	1	8	.9	3,330
		12	1.9	1,580
SHELLED CORN				
25	5	4	0.7	860
		6	1.6	380
20	3	6	.9	1,120
		8	1.5	670
18	2	6	.6	2,500
		8	.9	1,670
		12	2.2	680
16	1	8	.5	6,000
		12	1.0	3,000
		16	1.6	1,880

[1] Static pressure includes 0.25-inch allowance for loss from duct friction.
[2] Airflow (c.f.m.) per horsepower based on 3,000 c.f.m. of air at 1-inch static pressure.

ulating" or "on or off" controls. So far no one system of control has proved superior to all others. The purposes of controlled operation of the heat source, as opposed to continuous operation, are (1) to avoid high temperatures in the undried grain; (2) to avoid overdrying in the lower layers; and (3) to conserve fuel.

With supplemental heating the lower layers of grain tend to become drier than is necessary for safe storage. Excessive loss in moisture reduces the weight of grain, and if the grain is to be sold soon after drying, the seller loses money. For grain that is to remain in storage, some overdrying may be an advantage, particularly in the South or where insect infestation is a severe problem. Overdrying in the lower layers early in the drying period may be used to advantage if the drying is finished with unheated air. The overdried grain will then absorb moisture from the air, increasing the drying potential for the undried grain above.

Under many conditions the fuel saved by shutting off the heater may be more than offset by the longer period of fan operation to complete drying. Supplemental heating with or without automatic

controls is a useful, practical modification of in-storage drying.

Layer Drying

Table 1 suggests depths of grain for drying with unheated air. Limiting the grain to these depths may sometimes result in uneconomical use of storage bins. By drying successive layers of grain it is possible to fill the bin to a greater depth and dry the grain without spoilage. For example, corn with 25-percent moisture may be loaded to a depth of 6 feet in a bin. Air at a pressure of 1.6 inches is forced through the corn, giving a rate of about 5 c.f.m. per bushel. When this corn is dry, or shortly before, another 2- to 3-foot layer of corn is placed over the first and fan operation is continued. If the bottom layer is already dry, the second layer will start to dry immediately. Continued fan operation will complete the drying. A third layer may then be added. As each layer is added, the added resistance to airflow reduces the volume of air per square foot of floor area. By making each successive layer shallower than the last, the air volume per cubic foot of undried grain is maintained, and the drying can be completed before spoilage occurs.

The main limitation of in-storage drying is that as the grain depth increases, the power required for ventilation increases so fast that the power cost makes deep storage drying prohibitive. Column 3 in table 1 lists practical grain depths for various conditions. With depths greater than those listed, power costs will be high.

Layer drying permits drying greater depths of grain, and supplemental heating shortens the necessary period of fan operation. The combination of layer drying and supplemental heating can be used to decrease the overall cost of in-storage drying, by accommodating the drying process and the rate of harvesting to each other.

For example, when harvest begins a layer of shelled corn may be put in the bin and drying started immediately. The quantity of corn in this layer should be enough to cover the false floor evenly so that the air will come through the corn uniformly at all points. The supplemental heater may be used continuously to speed up drying. Before the top of this layer is dry another layer may be added. Each successive layer should be spread evenly. By adding shelled corn as harvesting progresses, there is never a large quantity of undried corn in the bin at one time. By this procedure the depth of grain dried may be substantially greater than if all the grain is put into the bin at once. Some manufacturers of drying equipment provide schedules of filling that will permit using the particular equipment to the best advantage and harvesting at a steady rate.

To use this procedure successfully it is necessary to determine occasionally how far upward the drying front has progressed, and additional undried corn is added accordingly. The results are best when each layer is added just before the drying front reaches the surface of the corn already in place. A simple test for the location of the drying front is to push a smooth stick or pipe down into the grain. When it reaches the drying front it will penetrate much more easily.

Drying Equipment

Ventilating Equipment

The ventilating equipment required for drying in storage consists of a fan and a power unit. The fan may be of either the propeller or the centrifugal type, but it must deliver the required volume of air against the static pressures indicated in table 1. Reliable manufacturers will supply air-delivery

ratings for the range of static pressures for which their fan equipment is designed. Fans that are unsatisfactory for grain drying include house, attic, or barn ventilating fans; those for blowing materials, such as silage and grain blowers; and the type used in fanning mills.

Electric motors are recommended for use in drying grains. Gasoline engines may be used, but they require more attention than electric motors.

The number of bushels that can be dried per horsepower is reduced materially as the depth of grain is increased. On the other hand, the cost of building a structure with a greater floor area, to reduce the depth of the grain, may more than offset the lower power requirement.

Adapting Storage Bins

Most farm bins can be readily adapted for drying grain. Figures 2 to 6, inclusive, illustrate methods of adapting common types of bins and general-purpose buildings for such drying.

The false floor of the circular metal bin shown in figure 2 is perforated metal. Cover the floor with an even layer of grain so that the air will be distributed uniformly through the grain. If a conveyor is to be used beneath the perforated floor, place this floor at least 16 inches above the permanent floor or ground. Otherwise, make the height of the false floor at least 10 to 12 inches. Support this floor on wood framing and concrete blocks or on other suitable supports.

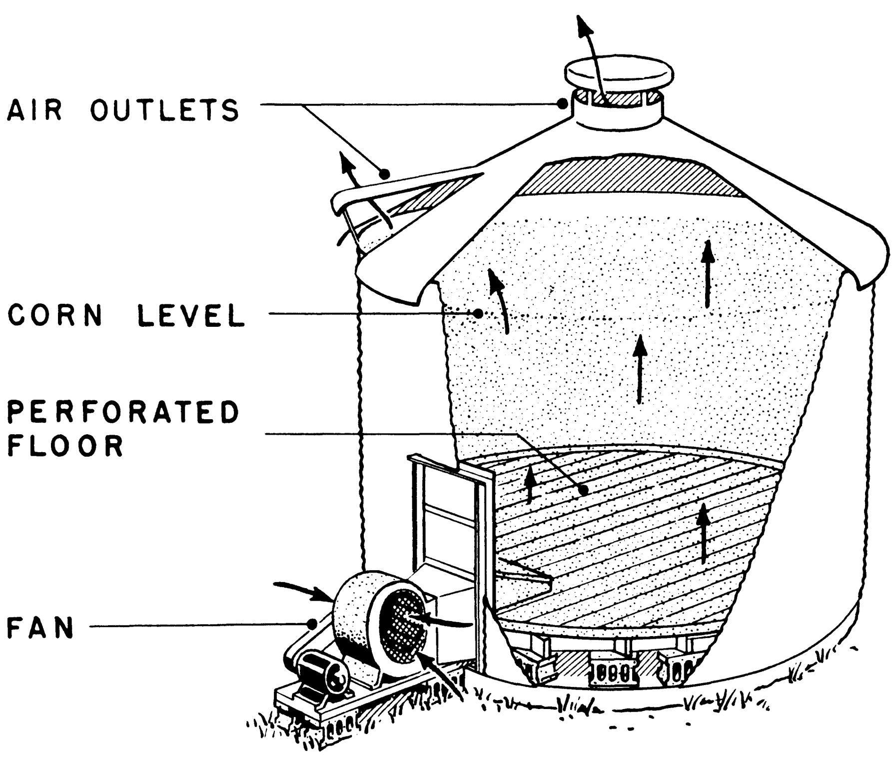

Figure 2.—Circular metal bin with false floor of perforated metal.

Lay the blocks so that air can circulate through the openings. If the bin has an earth floor, provide one block for each 50 bushels of grain that can be placed in the bin. For other floor materials, be sure that the bearing surface is adequate. Perforations in the false floor should amount to at least 7 percent of the total area of the floor. Mount the perforated floor in removable sections so that the space under the false floor may be cleaned easily.

Several companies make perforated metal sheets for false floors. You can get plans for installing the floors from these companies. Perforated metal floors can also be used in other than round bins.

Hardware cloth, as shown in figure 3, can be used instead of perforated metal sheets for false floors in drying bins. If openings are too large to hold the grain, cover the cloth with screen wire. Lay the concrete blocks so that air will circulate through them. Rows of blocks laid 3 feet apart will support grain to a depth of 15 feet; rows 4½ feet apart will support grain to a depth of 9 feet.

A duct system that can be used for unheated air drying in many types of bins is shown in figure 4. The duct system can be used in circular and rectangular bins, in overhead bins of combination crib-granaries, and in bins in a granary. For uniform air distribution, fill the bin with grain to a depth of at least 3 feet. The main duct, shown in figure 4 in the middle of the bin, could be located along one side, either inside or outside the bin. Build the lateral ducts in about 4- to 6-foot sections, so that you can remove them easily when emptying the bin.

Construction details for a duct system that can be used in several types of bins, as just described, are shown in figure 5. The main duct is generally rectangular, although it may be rounded or triangular. Allow 1 square foot of cross-section area for each 1,500 c.f.m. of airflow from the fan. For example: If the fan delivers air at the rate of 6,000 c.f.m., the cross-section area of the main duct should be at least 4 square feet. The duct could be 2 feet square or a triangle with 3-foot sides. Provide small screened openings along the top of the main duct so that air may pass upward to dry the grain above.

Space the lateral ducts, which can be rectangular, triangular, or rounded, so that the distance between them (center to center) is not more than one-half the depth of grain to be dried. If all the lateral ducts are the same length, compute the cross-section area required for each by dividing the cross-section area of the main duct by the number of lateral ducts. For example: With 8 laterals of the same length and a main duct cross-

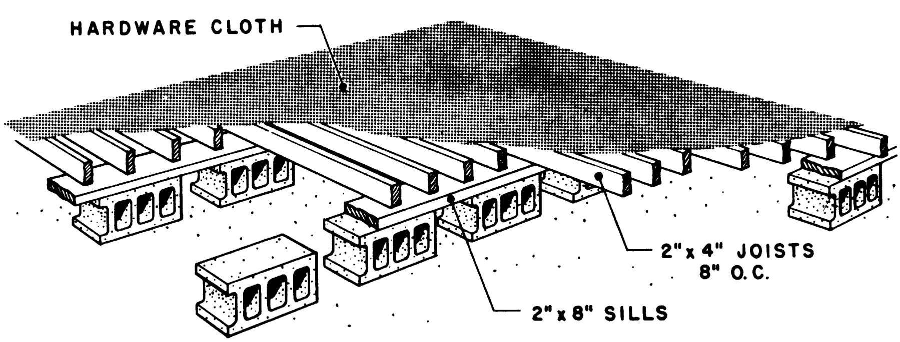

Figure 3.—Hardware cloth used as a false floor in a bin.

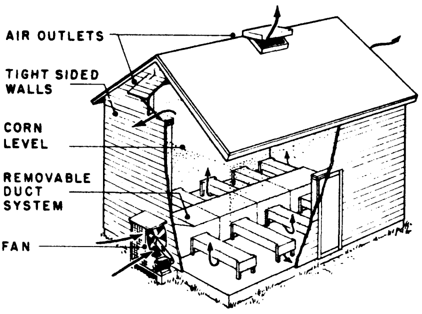

Figure 4.—Rectangular bin with duct system.

section area of 4 square feet, the cross-section area of each lateral will be 4 divided by 8, or ½ square foot.

The width of each lateral should be at least twice the height of its bottom edge above the floor. This height should be about 4, 6, 7, 8 and 10 inches for laterals spaced 2, 3, 4, 5, and 6 feet, respectively, from center to center.

In any case the total area for air passage under the sides of all the lateral ducts (height from floor to bottom of lateral times length for both sides) should be equal to at least one-fourth of the bin floor area.

If you use perforated metal sheets to make the laterals and the sheets have uniformly spaced perforations equal to at least 10 percent of their total area, you may set the laterals directly on the bin floor.

The combination of a central duct with a perforated floor is illustrated in figure 6. The spaces between the supports for the perforated sheets act as lateral ducts. These spaces should be deep enough that the air velocity will not exceed 1,500 feet per minute. Usually 4 inches is deep enough.

Air ducts on top of the floor are not as satisfactory as air distribution under the floor when thin layers of grain are being dried, such as in layer drying or in-storage batch drying. If drainage is not a problem, a trench along the centerline under the floor can be used as a central duct. This leaves the entire floor flat, and provides good distribution of air. This arrangement permits the use of a gathering auger. An auger is a convenience in emptying the bin, particularly when the bin is used for batch drying.

Weight Loss Caused by Moisture Reduction

Table 2 shows the amount of water in grains with various per-

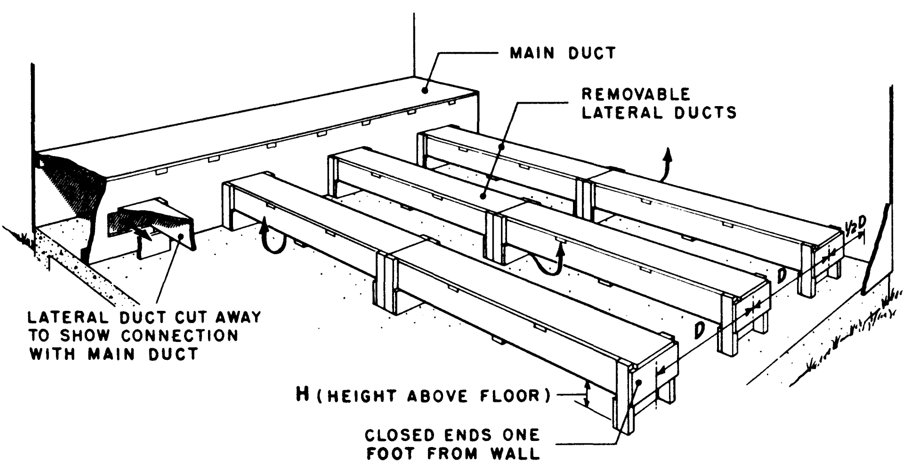

Figure 5.—Details of duct system for drying bin.

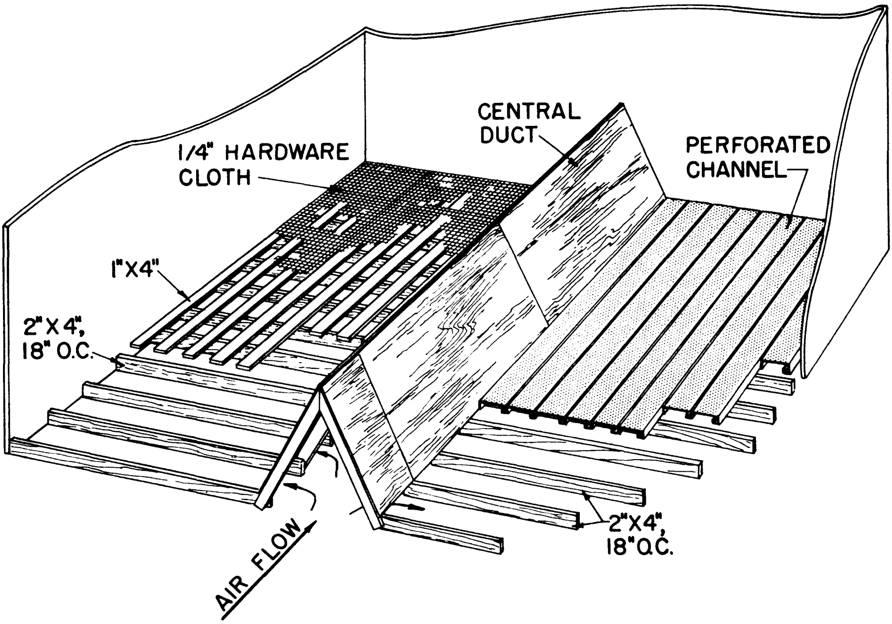

Figure 6.—A central duct in combination with a false floor.

TABLE 2.—*Pounds of water per bushel*[1] *of grain at different moisture-content percentages*[2]

Grain moisture content (percent)	Amount of water per bushel of— Shelled corn and grain sorghum (Pounds of dry matter per bushel = 47.32)	Wheat and soybeans (Pounds of dry matter per bushel = 51.6)	Oats (Pounds of dry matter per bushel = 27.4)
	Pounds	*Pounds*	*Pounds*
35	25.4	27.8	14.6
30	20.2	22.1	11.7
28	18.4	20.1	10.6
26	16.6	18.2	9.6
24	14.9	16.4	8.6
22	13.3	14.6	7.7
20	11.8	12.9	6.8
18	10.4	11.4	6.0
16	9.0	9.8	5.2
14	7.7	8.4	4.4
12	6.5	7.0	3.7
10	5.3	5.8	3.0
8	4.1	4.5	2.3

[1] A bushel is defined here as the amount of grain required to yield 56 pounds of shelled corn or grain sorghum at 15.5 percent moisture, 60 pounds of wheat or soybeans at 14 percent, and 32 pounds of oats at 14.5 percent.

[2] To determine the number of pounds of grain required to make a bushel at a given moisture percentage, add the pounds of water to the pounds of dry matter (shown at head of column). For example: To obtain the weight of corn, at 28-percent moisture content, to make a bushel, add the pounds of water (18.4) to the pounds of dry matter per bushel (47.32). This totals 65.7 pounds. It requires 65.7 pounds of corn at 28-percent moisture content to make a bushel (56 pounds) of 15.5 percent corn.

centages of moisture content. By using this table you can estimate the weight loss caused by drying (pounds of water evaporated). Subtract the weight of water per bushel after drying from the weight of water per bushel at the start of drying.

Another method of calculating weight loss is by the following formula:

$$\text{Initial weight} \times \frac{100 \text{ minus initial percent moisture}}{100 \text{ minus final percent moisture}} = \text{final weight.}$$

Then, initial weight minus final weight = weight of water lost.

For example, if 20,000 pounds of grain with a moisture content of 25 percent is dried down to 13 percent, the weight after drying will be $20{,}000 \times \frac{100 \text{ minus } 25}{100 \text{ minus } 13} = 20{,}000 \times \frac{75}{87} = 20{,}000 \times 0.86 =$ approximately 17,200 pounds. The weight of the water lost by evaporation is 2,800 pounds.

General Recommendations

Selection of Equipment

Choose the type of equipment best suited to the expected operations on your farm.

Consider possibility of using present storage buildings for drying.

Choose equipment that will give the required capacity without using air temperatures above about 140°F. for drying grain to be marketed.

Do not get inadequate equipment by underestimating the quantity or moisture content of the grain to be dried.

Consider what handling equipment, elevators, etc., will facilitate the overall operation.

Consult your insurance company about suitability of any heating equipment.

Consult your power company about availability of adequate power.

Operation of Equipment

Avoid mechanical damage to the grain during harvesting and handling.

Do not overload the drier. Accommodate the rate of harvesting to the drier capacity.

Keep fine particles and foreign material out of the grain.

Start harvesting and drying as soon as the grain can be harvested without damage.

Do not leave even small pockets of high-moisture or high-temperature grain in storage.

This publication supersedes Leaflet 331, "Drying Shelled Corn and Small Grain With Heated Air," and Leaflet 332, "Drying Shelled Corn and Small Grain With Unheated Air." Information on drying ear corn is given in Miscellaneous Publication 919, "Drying Ear Corn by Mechanical Ventilation."

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